Strong Correlation and Superconductivity

(Proceedings of the IBM Japan International Symposium, Mt. Fuji, Japan, 21-25 May, 1989)
(Springer Series in Solid-State Sciences, Vol 89)

edited by H Fukuyama, S Maekawa and A P Malozemoff

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This volume contains the proceedings of the IBM Japan International Symposium on Strong Correlation and Superconductivity which was held in Japan during May 21-25, 1989.

The recent activity in strongly correlated systems was motivated by the discovery of high temperature super conducting oxide (HITSO). From the very beginning, the usual normal and superconducting properties of these HITSO materials have convinced many workers that the usual BCS type pairing mechanism might not be very convenient for understanding the HITSO properties. This actually gives birth of the idea of strongly correlated electron (hole) mechanism.

It was Professor P W Anderson who first proposed that the essence for understanding the HITSO properties lies in the strong correlations among the electrons. This proposal leads eventually to the new concept describing electron correlations.

This volume deals theoretically, mostly the *t-J* type model and some experimental observations on the HITSO materials. The coexistence of itinerant and localized characters is symptomatic of the appearance of strong electron correlation and the less importance of the one electron theory. Following the Anderson's proposal that the strongly one band Hubbard model near half filling in the square lattice, includes essential physics of the Cu-oxide HITSO materials ; much of the theoretical studies has been done along this line. The simplest *t-J* type Hamiltonian can be written as

$$H_{ij} = -t \sum_{(ij)\sigma} C^{+}_{i\sigma} C_{j\sigma} + 2J \sum_{(ij)} \vec{S}_i \cdot \vec{S}_j$$

$$C_{i\sigma} = (1 - n_{i-\sigma}) C_{i\sigma}$$

with $C_{i\sigma}$ as an annihilation operator of an electron with spin at site i, $n_{i\sigma} = C^{+}_{i\sigma} C_{i\sigma}$ and $\vec{S}_i$ is a spin operator with $S = \frac{1}{2}$ at site i. This *t-J* model has been applied in HITSO with several approximations by different authors. One such approximation is that the electron or hole doping causes the spin defects with

electric charge on Cu sites so that the defects can be looked upon as holes on Cu sites. But there are controversies, how good these approximations are and what the physical parameters are in the real oxides when the model is applied to the HITSO systems. These problems have been theoretically dealt with by several authors. The t-J model has also been examined using a renormalized mean field theory and it has been shown that an instability exists towards flux phases at large J/t. The flux states have a collective gauge variable and exhibit superconductivity. Professor P A Lee treated the gauge field theory in the presence of a finite correlation of holes and describe the resulting superconducting behaviour. This theory also leads to a $T^{4/3}$ law for the normal state resistivity. Fukuyama and Matsukawa derived an effective Hamiltonian for the CuO_2 layers in presence of extra holes doped mainly into O-sites taking into account both on-site and intersite Coulomb interactions. In this way, several interesting theoretical approaches have been made to understand the mechanism of the complicated superconducting behaviour of the HITSO materials.

This volume also contains a number of experimental papers which suggest that there is quantitative change in the physical properties of $La_{2-x}Sr_xCuO_4$ when x changes from 0.15 to 0.30, when the material is no longer superconducting. Quite intriguing is the temperature-dependence of the spin lattice relaxation times that were reported from NMR experiments, where different lattice sites and hence internal variations of interactions may be probed. The energy dependence of the conductivity at low energies as obtained from tunneling data and a strong source of scattering by an unidentified continuum of states revealed by Raman scattering experiments, are put forward as indications that Fermi-liquid-type descriptions of the normal-state behaviour of these materials are inadequate. Photoemission data with high resolution show the energy cut-off at E_F and a linear rise of intensity with increasing binding energy. Other experimental studies like Andreev reflection, thermal conductivity, Hall effect, NMR and NQR studies in highly correlated metallic and superconducting Cu oxides, optical absorption in $La_{2-x}Sr_xCuO_4$, inverse photoemission and X-ray absorption spectroscopic studies of HITSO materials have also been reported.

However, the important question is still in existence namely, the magnitude and anisotropy of the energy-gap that develops with the onset of superconductivity in the materials. Various contributions have been discussed elucidating the underlying problems. A considerable influence in Tc by different isotopes of oxygen in (Ba, K)BiO_3 have been well discussed. It is surprising that this kind of oxides is different from the copper oxide variety. In spite of remarkable progress, one cannot claim to know the exact pairing mechanism and whether weak or strong coupling scheme should be applicable, nor are we certain as to what kind of

superconducting state is adopted for the HITSO materials. To have some ideas about all these problems this book would help a lot. Of course, to find answers to all such questions one has to depend much on the experimental results, how good materials we can prepare, and how well these materials could be characterized both in the superconducting and normate states. Study of magnetic behaviour (mostly superdiamagnetism), importance of antiferromagnetism in the pairing mechanism, oxygen-ordering mechanism etc. are yet to be thoroughly understood. This book would definitely provide enough information for such an understanding.

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Developments in Theoretical Physics (Theoretical Physics Seminar Circuit Lectures 1988, Vol 1)

edited by S M Roy, V C Sahni and M Barma

Oxford & IBH : New Delhi-Bombay-Calcutta, 1989
281 pages ; price : Rs. 250·00 (Soft cover) ; ISBN 81-204-0470-x

This book, about two hundred and eighty pages long, is an outgrowth of the Theoretical Physics Seminar Circuit (TPSC), a program of the Department of Science and Technology. Primarily aimed at increasing the level of scientific collaboration and sharing of information amongst researchers working in different parts of the country, the program provides financial support to chosen speakers for board and travel onto various research institutes. This book provides for a "wider dissemination of the contents of these lectures...a glimpse of some of the areas of contemporary theoretical physics research in India".

This volume is divided into three sections. The section A, comprising about one-half of the book, deals with the subject of elementary particles and fields ; contains nine lectures. The topics covered in this section are :

1. EPR paradox in particle physics (D Home) ;
2. Exact symmetries arising from inexact ones (N D Hari Das) ;
3. Interactions of cosmic string (T Vachaspati) ;
4. Euclidean Weyl fields (J Kupsch) ;
5. Anomalies, Schwinger terms and anomalous gauge theories (P Mitra) ;
6. Kaluza-Klein theories (M Sivakumar) ;
7. Extra dimensions in Cosmology (D Sahdev) ;

8. String vacua and renormalisation group (S R Das) and
9. Low energy supersymmetry (P Pandita).

The section B, consuming about 20% of the volume, deals with the interface of Nuclear and Particle Physics. A set of four lectures covering, 1. Relativistic two-body problem (R S Bhalerao) ; 2. Spin structure of the proton (M V N Murthy) ; 3. Quark gluon plasma (R V Gavai), and 4. J/Ψ production in heavy ion collisions (S Gupta), form this section.

The section C, approximately 30% of the book, is about condense matter and includes a solitary lecture on atomic physics. The subjects covered include, 1. Quantum jumps (S Lawande) ; 2. Exact and analytic results on antiferomagnetism (I Bose) ; 3. Charge and spin density wave superconductors (S N Behera), and 4. Gauge theory of line defects in elastic continua and liquid crystals (D Sahoo).

Most of the lectures are fairly self-contained ; some emphasize the original contribution of the lecturers ; others read more like reviews. The topics selected are contemporary, and except for the steep price (Rs. 250.00), this book should have a wide readership. It provides a valuable forum for physicists of this country to present their ideas and gain a measure of familiarity with each other.

The selection of topics appear to be too narrow for a physics community as large as the one in India. The theoretical physicists in this country will gain a great deal if the TPSC selectively allows scholars from the user agencies, such as the DRDO, the C-DAC and many others, to talk about the softwares they develop in their work. The doors should certainly be kept selectively ajar for our experimental colleagues who can enrich us enormously in our research, providing a balance in our minds between problems that are speculative and the ones that are investment grade.

The areas of theoretical studies dealing with general techniques, mathematical methods, developments in softwares and simulations seem important to be included in the TPSC scheme. If at all, scholars with expertise in these areas may be allowed longer periods over which they could interact with host institutes.

The TPSC program has just started. Fortunately, the editors are well aware of the problems, and in their own words, "hopefully in the coming years the volumes that will follow will cover all branches in equal measure".

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Neutrinos (Graduate Texts in Contemporary Physics)

edited by H V Klapdor

Springer-Verlag : Berlin-Heidelberg-New York-London-Paris-Tokyo-Hong Kong, 1988
vii+339 pages, 164 figures ; price : DM 84 (Hard cover) ; ISBN 3-540-50166-5

This is an excellent text book for Graduate studies in Physics of different Universities in India and in abroad.

This book is concerned with the properties of neutrinos which enriches the knowledge of the weak interactions. The role of neutrinos in Grand Unification is discussed in detail. The neutrinos are the constituents of the matter and their mass could determine the large scale structure of GUT and evolution that exp'ains the early Universe. The neutrinos are of astrophysical importance since these are the direct probes of processes in the course of collapsing stars.

The book is based on 10 review articles written by different experts of the field describing neutrino properties and other related problems to particle physics and neutrino astronomy. This book is well written for understanding the nature and properties of particle physics, astrophysics, cosmology and experimental aspects relating to neutrino oscillation, nuclear beta decay, lepton flavour violation.

The ^{76}Ge double beta decay experiments have been fairly described in the book. Attention has also been paid on double beta decay which is one of the rarest processes in nature.

The weak interaction process leading to the production of neutrinos and their emission from collapsing stars and newly born neutron stars has also described in the book. It is found from the book that theoretical predictions and expectations are in fairly good agreement with the luminosity and average energy of neutrinos observed from SN 1987A, provided they signalled the formation of a neutron star.

The cosmological sources of neutrons has also fairly projected in the book.

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Lectures on Modern Magnetism

by B Barbara, D Gignoux and C Vettier

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xii+231 pages, 128 figures, 22 tables ; price : DM 98 (Hard cover) ; ISBN 3-540-17558-x

The book under discussion is based on a set of lectures given by the authors at Beijing University in 1979. Textbooks on theoretical and experimental aspects

of modern magnetism are not many in number and the present work is a welcome addition to the existing list. There are fourteen chapters in the book dealing with experimental, material, phenomenological and theoretical aspects of magnets. The experimental methods described include magnetization and susceptibility experiments (chapter 2), magnetic structure determination using neutron scattering (chapter 5) and inelastic neutron scattering technique for the study of spin excitations (chapter 6). The last topic, very important in modern day experimental research, has however, been described rather briefly. The exposition of the other methods is good and the general principle behind such measurements is well brought out. The material aspects of magnetism that have been described in the book include magnetic bubbles (chapter 11) and coercivity (chapter 12). The section on magnetic domains and domain walls in chapter 11 is illuminating. The other chapters are mainly devoted to theoretical aspects. The introductory chapter gives a good review of quantum theory of magnetism and also discusses symmetry properties of magnetic systems using group theoretical concepts. The chapter on molecular field model and magnetic ordering explains at the end the method of Villain and Yoshimori which is an important technique but has seldom been included in other books on magnetism. The chapters on the paramagnetic state and magnetic excitations give a standard description of the topics except that crystal field effects have been extensively discussed in the context of real magnetic systems. This is also true for the chapters on 4*f* rare earth systems and ionic 3*d* compounds. The emphasis on the crystalline environment, knowledge of which is essential in understanding the statics and dynamics of real magnetic systems, is a valuable feature of the book. The chapter on magnetic excitations discusses spin wave theory for both ferromagnets and antiferromagnets but leaves out description of magnon bound states which have been experimentally detected in low dimensional magnetic systems like $CoCl_2.2H_2O$. There are two chapters on 3*d* metallic magnetism and the Stoner model. A comprehensive discussion of the topic of metallic magnetism is however lacking, the description of narrow band magnetism vis-a-vis the Hubbard model is altogether missing. The chapter on intermediate valency in 4*f* systems gives a short phenomenological introduction to the subject and does not attempt to highlight the conceptual and calculational aspects of the problem. The chapter on magnetic phase transitions does not contain descriptions of the important concepts like scaling theory and universality of critical exponents. Renormalization Group theory, one of the greatest triumphs of the modern theory of critical phenomena, has only a tiny section devoted to it. Landau's theory of critical phenomena has, however, been discussed adequately and the inclusion of multicritical phenomena adds to the information content of the chapter. An important omission in the book is the lack of and Index at the end. The references at the ends of the chapters are not often adequate. For

example, the chapter on intermediate valency in 4*f* systems does not refer to any of the several good reviews that have been written on the subject. The text of the book is, however, lucid and serves as an adequate introduction to the subject of magnetism. The book on the whole, should prove to be useful to the research workers working in the area of magnetism.

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Magnetic Properties of Metals : Compounds of Rare Earth Elements with Main Group Elements (Landolt-Börnstein, New Series, Group III, Volume 19, Part e)

edited by H P J Wijn

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xvi + 440 pages, 943 figures ; price : DM 1230 (Hard cover) ; ISBN 3-540-50338-2

In this volume, magnetic data on four different types of compounds of rare earth elements have been compiled. This includes rare earth compounds with Be, Mg, Zn, Cd or Hg, those with B, with Al, Ga, In or Tl and lastly compounds with C, Si, Ge, Sn or Pb. The literature prior to late 1987 has been surveyed. Any body familiar with the Landolt-Börnstein series will find the same meticulous literature survey and the thoughtful organisation which are the assets of this series. The importance of these data in the development of new magnetic materials with tailor made magnetic properties needs hardly to be emphasised. In view of this, this volume is unhesitatingly recommended to any Science and Engineering library.

Magnetic Properties of Non-Metallic Inorganic Compounds based on Transition Elements : Pnictides and Chalcogenides I (Landolt-Börnstein, New Series, Group III, Volume 27, Part a)

edited by H P J Wijn

Springer-Verlag : Berlin-Heidelberg-New York-London-Paris-Tokyo-Hong Kong, 1988
ix + 425 pages, 1076 figures ; price : DM 1150 (Hard cover) ; ISBN 3-540-18751-0

The magnetic data on pnictides and chalcogenides, published before late 1987 has been listed in this volume. Here, pnictides are defined as compounds which contain one or more of the group V elements (P, As, Sb, Bi or Bi) while

Chalcogenides as those with one or more of the group VI elements (S, Se, Te). Mixed systems containing both Group V and group VI elements are also discussed. The authors have to be commended for the careful organisation of the data. This volume will be useful to workers of diverse field and hence like all previous volumes of Landolt-Börnstein, will be a welcome addition to any science or engineering library.

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